Enactive Interaction and Enactive Modeling

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1 General framework

After their wide developments in the last 20 years, including domains as Interactive Computer Graphics, Human Computer Interfaces, Multimodal interfaces, Virtual/Augmented/Mixed Reality systems, we are at a end of a period in which all seems to be done.

However,
• due to the convergence between disciplines as different as Interactive Computer Graphic (ICG), Modelling and simulation of complex systems, teleoperation, telecommunication, autonomous and interactive robotics, Teleoperation, Telecommunications
• Around common concepts and new ideas and needs: Presence, believability, Immersion vs. Vis-à-vis, etc.
• and confronted to main technological evolutions
  - In chip integration and computer power
  - In progression of the networking
  - In changes in tranducers technologies
Interactive Computer Systems enter in new age and we are at a new cross point and at the beginning of a new period.

We envision that:
"*Beside "**Thinking machines**" as machines that can perform reasoning,*
*Beside "**Communicating machines**", as machines which allow us to communicate*
Complementarily with them,
*Computer sciences and Interfaces technologies must include the objective to design a **"Sensible Machine",***
Adapted to our multisensory-motor intelligence,
Able to be a generic interface between humans senses and external universe
As a third and last component to complete the Computerized Environments."
(Reference: Enactive project original document)

This lead to develop a new concept
At the junction of:
• Informatics as technology of information processing and programming languages
• Signals and systems disciplines as technologies of control of complex systems, close-loop regulation, real time simulation of complex dynamic systems.

2 States of the art

The three states of the art, respectively related to the technology of haptic interfaces, action-vision and action – audition cooperation in mediated computerized systems, including some critical psychological issues, have been produced by the Joint Research Activity "Technology of Enactive Interfaces"

(Leader: A. Luciani) of the Enactive Project. They lead to identify that multisensory interfaces come up against a double problem of "complexity":

• the first, we called **"technological complexity"** mainly based on scaling problems in modelling interacting systems:

• The second, we called **"functional complexity",** mainly based on organisational problems in interactive tasks.

2.1 Type of technological complexity

It is difficult nowadays to implement cooperation between interacting systems (figure 1):

(1) which address the complexity for vision and audition, more generally for "exteroceptive feedbacks" (typically, interactive geometry and visual rendering and signal – based sound synthesis). We called it metaphorically "complexity for the eye and the hear".

(2) (2) which address the complexity for the manipulation (typically haptic systems and interaction, physically-based modelling, dynamic complexity). We called it metaphorically "complexity for the hand".

(3) In addition, these two types of complexity are non yet compatible from the point of view of the modelling theories and computer technology.

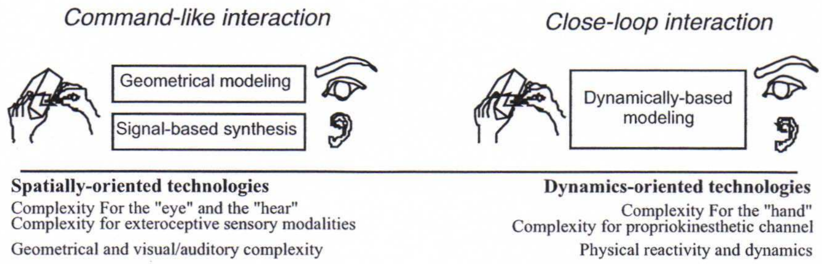

Figure 1. Type of technological complexity – Scaling Problems

Most of the technologies are on the left side. A few number are on the right side (see figure 2 "exemplary technological platforms").

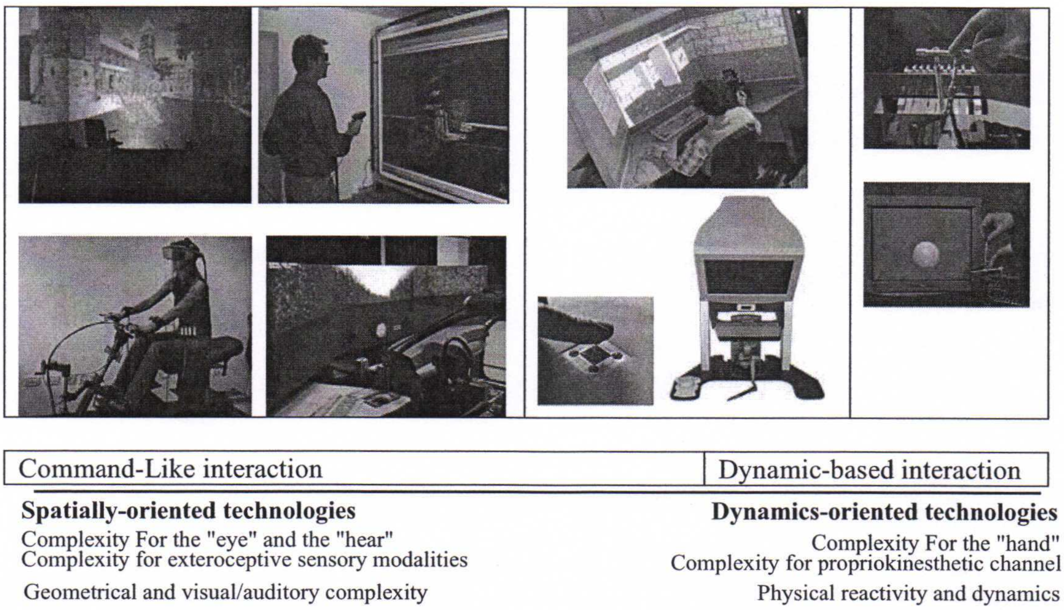

Figure 2. Positioning of exemplary platforms on "technological type of complexity axis"

Main unsolved questions are:

• The increasing of the complexity of the virtual scenes in terms of computed elements

• But precise representation with the corresponding questions of level of details adapted to he tasks and to the perception, size and density of the represented data, etc.

⇒ spatially large vs. small

• The versatility of the demands of the users: high visual realism, large geometrical scenes, huge type of objects (from wires with nodes in surgical applications to buildings for architecture and city navigation or natural landscapes). But precise haptic (i.e. local) sensations

⇒ distant vs. local

• The variability of the time constraints in terms of real time simulation, latency and synchronization

⇒ temporally large vs. small

• The versatility of the computerized environments in terms of types of machines and architectures: centralized or distributed environments, networked or embedded systems, processors communications,

⇒ Large vs localized

• New questions as the role of the auditory modality, starting from specific uses like to help visually impaired people or to define new instruments for musical arts and triggering new knowledge in the role of the sounds in the everyday life and the role of computerized sounds in multimodal interfaces for general uses

⇒ Space representation vs. object representation

2.2 Functional complexity

Interactive systems can be classified in three groups (Figure 3):

• those mainly oriented for spatial interaction (large space navigation, exploration, localisation), implementing more or less the concept of immersion

• those mainly oriented for the local manipulation (haptic manipulation, local rheological properties of matters, etc.), implementing the concept of "tool", "instrument", etc. as an extension of human organology.

• Between both, there is a vis-à-vis fuzzy stage, in which the status of interacting object is still changing: from a part of the environment (near the hand, just selected) to a part of the human body (selected in hand) and vice –versa. This stage is the usual stage implemented in conventional interactive computer graphics.

However, in everyday or professional tasks, we are trading-off permanently between "objects as a part of our environments" to "objects to act-on and –with". The status of what we are interacting with is not fixed. It is still changing. That is represented on, the following figure 3.

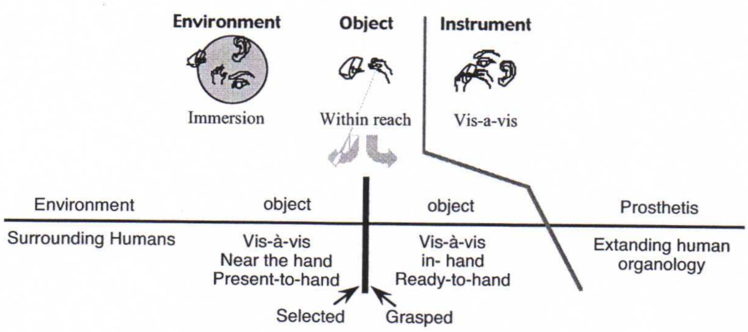

Figure 3. Functional complexity: "the transformation of the functionality of with what we are interacting"

Note:

The words "Present-to-Hand" and "Ready-to-Hand" are inspired from the objective philosophy Heidegger's work "Being and Time" (1927).

• Most of the mediated computerized technologies are located at a specific place : immersive environment, vis-à-vis systems, tools and instruments
• Most of them are located on the left side of the grey line
• Among them, most are located near the black line (main stream of Interactive Computer Graphics)
• A few of them are located on the right side of the grey line
• No of them allow to traverse from the left to the right and vice-verse: the main bottleneck being near the black frontier: (observed) / "selected to grasp" / act-on and –with.

Figure 4 positions exemplary platforms on the "type of technological complexity axis".

⇒ This bottleneck is all the more critical because of the wideness of the real and potential uses traversing all the fields of human professional and daily activities: industrial design and maintainability, medical and surgical planning and therapies, didactical uses, artistic and cultural developments, knowledge accessibility, etc.

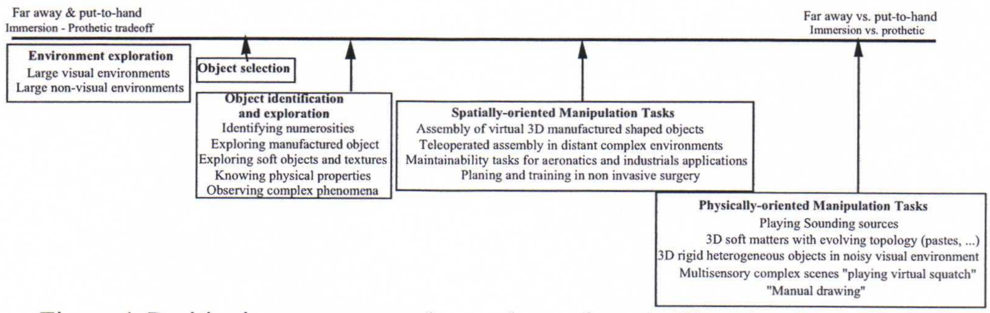

Figure 4. Positioning some exemplary tasks on the axis "Functional complexity"

3 Bottlenecks to be tacked in the next future

3.1 Enactive Interaction

The first bottleneck we detected is related to technological complexity.
Among all the know and not still solved spatially-based problems, there are really problems to implement dynamically-based manipulation tasks.

The technological critical components are thus:

• Force feedback systems and interaction

Force feedback systems are coming out of their teenager phase. The developments have to be stimulated to enter in an adult and really usable phase.

⇒ New integrated systems have to be designed with improves performance to render them adapted to the manipulation tasks: morphological versatility and adaptation, dynamical adaptation to the tasks, security, compactness.

• Physically-based and dynamically-based modeling.

Interactive Geometrical modeling is in its mature phase. Conversely Interactive Dynamic and Physical modeling are in infancy. They are the counter part – the best companion – of haptic interaction. Geometrically-based physical modeling as finite elements methods are not yet adapted to interactivity. Most of physical and dynamic approaches are "one-shot" approaches, designing specific non reusable models. Physically-based particle modeling is more general but it is still yet inadequate for spatial visual rendering.

⇒ New interactive modeling systems have to be designed allowing open general purpose dynamic modeling software and managing the cooperation with geometrical modeling and signal-based modeling software.

• Synchronous real time computation and multisensory rendering

Most of the developed platforms are asynchronous platforms, trying to manage tradeoff between dynamic veracity and the high communications and computations delays of the current technology. This reduces extremely the fields of uses to medium-scale behaviors of interacting objects (not too much rigid, not too much precise).

⇒ New computer-devices architectures have to be designed, with high local reactivity and low latency, small interacting very fast components, taking more benefit of embedded systems.

3.2 Enactive modeling

The second bottleneck we detected is related to "functional complexity".
As said before, no real tasks implement only a "single functionality of object". Real tasks are constantly playing with various functionality of object. We are moving on the axis "from thing of the environment to be perceived to thing as tools to act" and vice-versa.

According to the facts that:
• the underlain necessary technology are completely different: geometry and signal in one hand, dynamics in other hand
• the computer architecture and foreseen limitations of computer chips at the horizon of 2010 will continue to render them quite incompatible: mainly focused on the power and bandwidth capabilities for the first (well supported by the commercial evolution of computer chips) and mainly focused on reactivity, synchronicity and low latency between inputs and outputs for the second (less supported by the commercial evolution of computer chips)

⇒ Implemented computer models and interaction processes have to be dynamically flexible, versatile, adaptive during the performance of the task, this transformation being under the control of the functionality of the object and interaction along the task. We called that "Enactive Modeling", in the sense that the modeling process itself is an interaction situation that will be adaptive, similarly the processes of Enaction and autopoïesis in living organisms.

⇒ Tasks / Technology / human capabilities have to be analyzed "together to be able to create find the optimal and generic point for the real implementation. That will lead to set-up theoretical and pragmatic basis of a new methodology and know-how in uses implementations in which the three partners "technology of interaction / users / uses" are not considered separatly, as a kind of "new ergonomy of interactive mediated computer tools".

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She is the head of ICA (Informatique et Création Artistique) Laboratory at Institut national Polytechnique de Grenoble (France). She is member of ACM, IEEE and EUROGRAPHICS and of scientific committee of WordHaptics, EuroHaptics, Graphicon and Cyberworlds Conferences. She stated with her colleagues the development of force feedback devices in 1976, leading to several patents. She worked with her colleagues in real time physically-based simulation for multisensory situations. She is the Deputy Coordinator of Enactive Interfaces Network of Excellence. Her fields of Expertise are: Virtual Reality, Human Computer Interactions, Computer technology and information technology, Computer Graphics and Animation, Computer Music and sound synthesis, Haptic devices and haptic interaction, Real time simulation and signal processing